Appendix

Developmental Language Disorders: diagnostic criteria and available tests in the Chilean educational system

In Chile, the diagnosis of Developmental Language Disorders (DLD) in public schools, as well as subsidized schools, is regulated by the decree of law n°170 (2009). Both public as well as subsidized schools receive public funding; public schools are fully funded by the state, subsidized schools are partially funded by the state, and co-funded by the parents or private institutions (i.e. foundations, churches). The funding model created three layers of socioeconomic segregation in the educational system, as children from higher-income families would attend private schools. If the families were able to pay a relatively small amount of money their children would attend subsidized schools with a co-funding from parents, whereas if the family had a relatively low income, their children would attend public schools or schools partially funded by private institutions. This model has been changed, starting in 2017. After this reform, subsidized schools had to decide whether they became fully funded with private resources or funded by the state with a co-funding by private institutions. The reform meant that parental funding has ended for subsidized schools, reducing the previous socioeconomic differences in the access to education. The educational reform that changed the funding system was implemented in 2017, during the last year of data collection for the studies presented in the present Dissertation.

As for the children´s language assessments, the first referral for assessment is usually after parents', paediatrician's or teacher's concerns regarding the language development of a child. In Chile, children attend the paediatrician for health controls at least once a year. A delay in language development can result in a DLD diagnosis after the age of 3, whenever the child performs below the norm, as described later in this text. The decree of law states that the diagnosis must be done by a phonoaudiologist (speech therapist), and must consider the child´s clinical history, a health exam, such that visual, hearing, or any impairment that may affect learning abilities can be excluded, as well as possible other relevant information regarding the personal history of the child and his/her family, that may affect language development. Additional psycho-pedagogical assessments are needed, together with the physical evaluation of articulatory and auditory organs. In order to gather all the information required, children must be assessed by at least a medical doctor (paediatrician, neurologist, psychiatrist or general practitioner), a teacher specialized in educational-special-needs and a phonoaudiologist. Whenever one of the experts suspects an emotional

or cognitive difficulty, a psychological report must be provided; when hearing impairment is suspected, an audiological examination is required. Severe physical or cognitive deficits are exclusion factors for a DLD diagnosis. In case children are found to also present other difficulties (such as auditory, visual, or cognitive difficulties) other specialists must assess these particular impairments (neurologist, otolaryngologist, ophthalmologist, psychologist or psychiatrist). To receive the diagnosis DLD, the child must present a delay in development of at least two out of four areas: phonology, morphosyntax, semantics or pragmatics. The areas of weakness are assessed by the different tests. Additionally, in Chile, DLD is defined as a transitory difficulty and is therefore expected to be solved after adequate professional support, given in schools or educational institutions by teachers for children with special needs and by phonoaudiologists. Children are referred to special education after a delay in language has been detected usually starting at the age of 3. Right after the diagnosis, children are referred to special education, where support to overcome language difficulties is given in the four areas of difficulties described above. If the child fulfils all the inclusion and no exclusion criteria mentioned above, he or she is assessed with three tests: TECAL, for morphosyntactic and semantic receptive skills; the ´Screening test of Spanish grammar´ (STSG), also for morphosyntactic skills (two subtests, receptive and expressive language); and TEPROSIF-R, for phonological skills. Complementary protocols can be used to assess pragmatics, such as the protocol by Luis Martínez (L. Martínez, 2001), which tests for different pragmatic skills (to take turns, pauses, appropriate referring to objects or people, and topic development). Due to the supposed-to-be transitory condition of DLD, children diagnosed with DLD are usually assessed once a year, at the end of the academic year.

For children older than 6 years, the diagnostic procedure comprises the same general examination. That is, children are examined for physical and cognitive development, and assessments of oral language and pragmatic language skills are conducted. As for the tests applied, the specialists decide on which tests to use to complement the diagnosis, using, in most cases, the tests mentioned above.

After being diagnosed, children attend training in one-to-one or small group sessions (maximum of three children). Each session lasts at least 30 minutes and takes place once a week. Additionally, the classroom teacher receives the support

of a teacher specialized in children with special educational needs (10 hours per week). This specialist support is given to all children with special needs in the classroom, and not only to DLD children (*División de Educación General Unidad de Educación Especial*, 2013).

The children included in the current Dissertation, were diagnosed according to the protocols described above. They all fulfilled the requirement of a delay in development in at least two areas of difficulty during the last assessment by the end of the year prior to participating in our studies. Additionally, as we could see in their educational records, 18 children who had been diagnosed with DLD, had at least two tests, once a year, corroborating their delay. However, we cannot verify the specific procedures taken for the diagnosis of each individual child, as we did not have access to their previous medical or educational records. Moreover, we did not have access to the previous educational or medical records of the remaining 24 DLD children, and we therefore do not know how many times they were diagnosed prior to the diagnosis used in the current studies. Nevertheless, because their age at the moment of testing was 6;2 (y;m, mean age), it is highly probable that they all had been diagnosed at least two times.

The sample analysed in the present Dissertation included 60 children (42 DLD and 18 TD; mean age at inclusion 6;1 (y;m), std. dev=1.01 years). Thirty-five participants were male; eighteen attended schools classified as low-SES, while the remaining 42 attended schools classified as mid-SES. All participants were monolingual Chilean-Spanish speakers. All children in the DLD group had their last diagnostic assessment by the end of the academic year prior to their inclusion in our study.

Test Battery

As previously mentioned, there is a set of tests used to diagnose children with DLD in Chile. Below we describe the tests that are used, and requested by law, for the funding support for indicated cases, for children with DLD. These obligatory tests are: Test for auditory comprehension of language (TECAL), Screening test of Spanish grammar (STSG: Chilean adaptation), and the Test for phonological simplification processes (TEPROSIF-R: Test para evaluar procesos de simplificación fonológica). Additionally, we describe the tests that were used

in this Dissertation to better specify the differences between DLD and typically developing (TD) children. These additional tests are: DIP (Illmer, 2013), and the Test battery to explore verbal skills for the assessment of learning disabilities (BEVTA: Batería de Exploración Verbal para Trastornos del Aprendizaje).

TECAL: Test for auditory comprehension of language

The TECAL (Pavez, 2003) is a Chilean adaptation of the ´Test for auditory comprehension of language´ by Carrow (1973), which has English and Spanish versions. The adaptation comprised the replacement of items in the Spanish version whenever they were not of common use in Chilean-Spanish, keeping the characteristic that each item tests (e.g. word inflection). The TECAL is standardized for Chilean children from the age of 3;0 to 6;11 (y;m), and consists of three sections that test for vocabulary, morphology and syntactic skills. The test items in the different categories may vary with respect to word class, morphological constructions, grammatical categories and syntactic structure. The test items include nouns, verbs, adjectives, adverbs, morphological endings, pronouns, prepositions, and interrogatives; syntactic complexity is varied. During the assessment, the child is presented with three pictures and asked to point at one, after the instruction given by the examiner. The TECAL consists of three subtests/parts. In the vocabulary part the child is expected to identify nouns, adjectives, verbs and adverbs. For example, for testing nouns, the child is presented with a picture of a flower, a rabbit and a butterfly; the child is then asked to point at the rabbit. For testing adjectives, the child is presented with the picture of three cars and is asked to point to the one in the middle. The total number of items in the vocabulary section is 41. During the morphology part, the child is expected to understand word inflections, negative structures, prepositions and pronouns. As an example of the negative structures, the child is presented with a picture of a girl jumping and a boy standing, the second picture shows both the girl and the boy jumping, and the third picture shows both the girl and the boy standing. The examiner then says ´Ni el niño ni la niña están saltando´ (nor the boy nor the girl are jumping), and the child must point at the correct picture. The morphology section has a total number of 48 items. Finally, in the syntax part the child is expected to understand imperative sentences, tacit subjects, subordinate sentences, direct and indirect complement. For example, for the tacit subject, the child is presented with a picture of one boy with an ice

cream, the second picture shows two boys with one ice cream each, and the last picture shows three boys with one ice cream each. The examiner then says: ´tiene un helado´ (has an ice cream), again the child must indicate the correct picture. There are 11 items in total in the syntax section.

The TECAL test´s manual reports validity tests, in which TD children, of different ages and from low-SES background were tested. The TD age-groups consisted of 30 children between 3 and 3;11 (y;m), 30 children between 4 and 4;11, 30 children between 5 and 5;11, and 30 children between 6 and 6;11. Additionally, children with language difficulties (of different natures) were compared to TD children. The language difficulties group consisted of 10 dysphasic children with comprehension problems(mean age= 5;6), 10 children with low- to mid-cognitive deficit and receptive language difficulties (mean age= 11;4), and 10 DLD children with only expressive difficulties (mean age=5;3), who showed no significant comprehension difficulties, as assessed by the receptive subtest of the STSG (see below). TD children were matched by age, sex and SES with the DLD group and compared on their performance. The results showed a significant difference (F=200.92, p<0.001) between the different age ranges within the 120 low-SES TD children. Additional analyses showed a significant difference between the 30 children with language difficulties and the matched 30 TD children (t=6.78, p<0.001). When the three language difficulties subgroups are independently compared to 10 matched TD children, the results differ. The dysphasic group, as well as the group with cognitive deficit showed poorer results as compared to TD children (t=4.22, p<0.05 and t=9.2, p<0.001 respectively). In contrast, no difference was reported between the DLD group with an expressive deficit only and matched TD children (average score: 68.1 and 79.2, respectively; standard deviation is 14.1 and 11.4, respectively; t=1.93). Reliability studies, reported in the test´s manual, assessed the test-retest reliability. From the group of 120 TD children assessed in the validity study, 40 children were re-tested 15 days after the first assessment. Additionally, all 30 children with language difficulties were re-tested 15 days after the first assessment. No significant difference was found between the first and second assessment for either group (TD or language difficulties). For other studies using TECAL as a standard test for DLD diagnosis in Latin America, see: Miranda et al., 2019; Núñez et al., 2017; Polo & Acuña, 2018; Figueroa-Leighton, Crespo & Sepúlveda, 2018.

STSG: Screening test of Spanish grammar (Chilean adaptation)

The STSG (Pavez, 2003) is a Chilean adaptation of the ´Screening test of Spanish grammar´, by Toronto (1976), for Chilean children up to 6;11 (y;m). It consists of two subtests, a receptive language test, and an expressive language test. In both tests, syntactic structures are tested; each test has a total number of 23 items. In the receptive subtest, the task of the child is to understand and interpret an orally presented sentence, and to point to the corresponding picture (out of four alternatives). As an example, there are four pictures, one shows a girl eating, the second one shows the girl moving her hands, the third one shows a boy standing and the fourth one shows a boy sitting. The examiner then says: ´El niño está sentado´ (the boy is sitting), ´El niño no está sentado´ (the boy is not sitting). The examiner then says ´Ahora muéstrame ´el niño está sentado´´ (now show me ´the boy is sitting´). In the expressive subtest, the examiner says two sentences, while showing two drawings, but without pointing to any picture. The examiner then points to one of the pictures, and asks the child to repeat the related sentence, among the two initially given. The child is thus expected to remember the two sentences, and correctly interpret the drawing and sentence presented. For example, a picture of a boy drinking from a glass and a picture of a girl drinking from a glass, are shown together. The examiner then says: ´El niño está tomando leche´ (the boy is drinking milk), ´La niña está tomando leche´ (the girl is drinking milk). The examiner then asks: ´¿Cuál es éste?´(Which one is this one?), pointing at the boy drinking milk.

Validity tests reported in the test´s manual shows the result of a study in 120 TD Chilean children from low-SES. All children showed normal hearing, IQ within the normal range and had Spanish as their mother tongue. Additionally, 30 TD children were compared to 30 DLD children. Children were included in the DLD group if they had normal oral comprehension skills, but a delay in expressive language acquisition and phonological difficulties. Additionally, children were interviewed to check for their discourse skills. Age ranges studied were: 3 to 3;11 (y;m), 4 to 4;11, 5 to 5;11 and 6 to 6;11. A significant difference was reported in TD children between all age ranges ($F=43.12$ for the receptive subtest and $F=60.52$ for the expressive subtest, $p<0.001$ for both subtests). No gender difference was found. Moreover, children with DLD (n=30) showed poorer performance ($t=3.42$ for the receptive subtest and $t=7.57$ for the expressive subtest, $p<0.01$), when

compared to TD children. The reliability study reported in the test´s manual was conducted by administering a re-test eight days after the first test. Twelve children participated in the test-retest study. The results indicated significant correlations between the two assessments (r=0.83 for the receptive subtest and r=0.77 for the expressive subtest, p<0.001 for both subtests). Diverse studies have used the STSG to explore language development in DLD and TD children (Crespo & Silva, 2019; Alfaro, Crespo & Alvarado, 2016; Coloma & González, 2001).

TEPROSIF-R: Test para evaluar procesos de simplificación fonológica

The TEPROSIF-R (´*Test para evaluar procesos de simplificación fonológica* ´, Test for phonological simplification processes. Pavez; Maggiolo; Coloma, 2008) assesses phonological simplifying processes in children up to 6 years and 11 months old. It tests for syllable structure, assimilation and substitution. During the test, the examiner shows a picture and gives a full sentence, then, the examiner shows a second picture and tells a second sentence, that is incomplete. The second sentence is related to the first picture, and the child must identify the missing item and repeat it (e.g. ´Mira, aquí hay un pato´, ´Look, here is a duck´ showing the picture of a duck; ´ y ahora mira acá, en el agua está el...´, ´now, look here, the ... is in the water´, showing a picture of a duck in the water). Items tested correspond to 37 monosyllabic and polysyllabic words. Responses are transcribed and analysed searching for the phonological simplification processes specified below. The quality of syllable structure production is assessed by checking for eight processes (a literal translation from the test manual is given): reduction of consonant groups (e.g. ´/pátano/´ instead of ´/plátano/´), diphthong reduction (e.g. ´/pénte/´ instead of ´/puénte/)´, omission of syllable coda (e.g.´/patalón/´ instead of ´/pantalón/´), coalescence (e.g. ´/alfómma/´ instead of ´/alfómbra/´), omission of unstressed elements (syllable or single phonemes; e.g. ´/_fómbra/´ instead of ´/alfómbra/´), omission of tonic syllable or one of its phonemes (e.g. ´/marí_sa/´ instead of ´/maripósa/´), addition of phonemes or syllables (e.g. ´/níndio/´ instead of ´/índio/´) and inversion of phonemes or syllables (e.g. ´/tenéfolo/´ instead of ´/teléfono/´). As for the assessment of number and type of phoneme assimilations, there are nine processes analysed: identical assimilation (e.g. ´/bubánda/´ instead of ´/bufánda/´), labial assimilation (e.g. ´/plátamo/´ instead of ´/plátano/´), dental assimilation (e.g. ´/madipósa/´ instead of ´/mariposa/´), palatal assimilation (e.g. ´/kuayérno/´ instead of ´/kuadérno/´), velar assimilation (e.g. ´/gufánda/´ instead

of ´/bufánda/´), assimilation of liquid phonemes (e.g. ´/kualérno/´ instead of ´/kuadérno/´), nasal assimilation (e.g. ´/anfómbra/´ instead of ´/alfómbra/´), vowel assimilation (e.g. ´/elfómbra/´ instead of ´/alfómbra/´) and syllabic assimilation (e.g. ´/didisáurio/´ instead of ´/dinosáurio/´). For the assessment of number and type of substitutions, 16 processes are evaluated: aspiration of the closing phoneme of the syllable (e.g. '/pehnéta/' instead of '/peineta/'), backing (e.g. '/kren/' instead of '/tren/'), fronting (e.g. '/buánte/' instead of '/guánte/'), consonant labialization (e.g. '/trem/' instead of '/tren/'), stopping of fricative consonant (e.g. '/kiráfa/' instead of '/xiráfa/'), frication of occlusive or affricate phoneme (e.g. '/fuénte/' instead of '/puénte/'), substitution of a fricative phoneme by another fricative phoneme (e.g. '/alsómbra/' instead of '/alfómbra/'), consonant voicing (e.g. '/kaberusíta/' instead of '/kaperusíta/'), loss of consonant voicing (e.g. '/kitáda/' instead of '/gitár 'a/'), semivowelization of liquid phoneme (e.g. '/pjátano/' instead of '/plátano/'), substitution of a liquid phoneme by another liquid phoneme (e.g. '/kapelusíta/' instead of '/kaperusíta/'), substitution of a liquid phoneme by anon-liquid phoneme (e.g. '/dinosáubio/' instead of '/dinosáurio/'), substitution of a non-liquid vocalic or consonantal phoneme by a liquid phoneme (e.g. '/elifísio/'instead of '/edifísio/'), nasalization (e.g. '/ánto/' instead of '/áuto/'), oralization of a nasal consonant (e.g. '/bufálda/' instead of '/bufánda/'), vowel substitution (e.g. '/puénta/' instead of '/puénte/').

Validity analyses of the TEPROSIF-R, reported in the test´s manual, were performed in 620 children, from low-mid- to high-mid SES. Children were recruited from different regions of Chile. A significant negative correlation ($r=-0.64$, $p<0.001$) was found between age (months) and the sum score (combining all processes) obtained for phonological simplification processes. Additionally, ANOVA analyses showed a significant difference ($F= 139.5$, $p<0.001$) between the age ranges studied (3 to 3;11 (y;m), 4 to 4;11, 5 to 5;11 and 6 to 6;11). Moreover, a significant difference was also reported between 44 TD children and 41 DLD children from language schools, diagnosed according to general regulations by phonoaudiologists (Mann-Whitney $U= 257.5$, $p<0.001$). Test reliability is reported by means of the Cronbach´s Alpha; $\alpha=0.9$. Different studies have explored the development of phonological processes in TD and DLD in Spanish speaking children, using TEPROSIF-R (Pavez et al, 2013; Coloma et al., 2010; Alfaro et al., 2016; Pavez et al, 2009).

DIP

To assess receptive language skills, we used the DIP (Illmer, 2013). The DIP is a test standardized for Chilean children up to 6 years and 11 months. The DIP follows the directions of the curriculum as established by the Ministry of Education in the BCEP (´Bases curriculares de Educación Parvularia´, Curricular bases for nursery education; 2001), testing for the performance at various skills, as expected for the age and SES of the children tested. To test these skills, the DIP considers the learning achievements described in the ´Mapa de Progreso de la Educación Parvularia´ (Map of progress in nursery education), which systematizes the directions given by the BCEP. During the test, the child must touch the screen of a tablet, selecting the correct item. Some of the domains assessed are oral language, quantification and logical-mathematical reasoning. The DIP has different tasks to assess these domains. For example, phonological awareness is assessed by testing syllable segmentation and identification of initial and final phonemes; mathematical skills are assessed by solving simple math problems; logical-mathematical reasoning is assessed by the ability to find patterns and complete sequences. Additionally, similar to the TECAL, the DIP tests for identification and comprehension of nouns, adjectives, verbs, pronouns and adverbs. As previously described for the TECAL, the child must select the item, among two or three options presented, that best suits the sentence orally given (e.g. ´La fruta más grande´ (the biggest fruit), a small orange, a medium apple and a large watermelon are shown). In the current Dissertation, only items with a receptive language component were included in the analyses. The reported validity study included 360 children (183 male participants), with ages ranging from 3 to 6;11 (y;m) years, divided in 4 age groups (79 children in 3 to 3;11, 91 in 4 to 4;11, 97 in 5 to 5;11 and 93 in 6 to 6;11). The results showed significant differences between age groups ($p<0.001$; no F-value reported). Additionally, children studying in public schools showed poorer results than children attending subsidized or private schools, probably reflecting the SES effect on children´s development ($F=9.62$, $p<0.001$). Reliability reported for the test corresponds to Cronbach´s Alpha =0.7 (Illmer, 2013).

BEVTA: Batería de Exploración Verbal para Trastornos del Aprendizaje

Additionally, we applied the BEVTA test (´Batería de Exploración Verbal para Trastornos del Aprendizaje´, Test battery to explore verbal skills for the

assessment of learning disabilities (Bravo & Pinto, 1995). It is used to assess some dimensions of oral language and basic psycholinguistic processes important for learning. The most important areas assessed by BEVTA are receptive oral language, short-term attention to oral stimuli, semantic abstraction, vocabulary, determination of verbal categories and sequence perception. We applied this test because, although no test for the diagnosis of reading difficulties is specified in the decree of law n°170, BEVTA is regularly used to support the diagnosis of reading difficulties in the Chilean educational system, and adds information about oral comprehension, which was important to explore the differences between children diagnosed as DLDe (with expressive difficulties only) and DLDer (with expressive and receptive difficulties). Although BEVTA does not directly assess reading skills, research in Chilean children has shown that results in the BEVTA distinguishes between children with good and poor reading skills, with TD children generally showing better results than children with specific reading disability (SRD) (Bravo, 1990; Bravo, 1995). Additional tests, for word reading and phonological awareness are also used in general, to support the diagnosis. In the current Dissertation, we complemented the use of BEVTA with a reading fluency test, measuring word and pseudoword reading, and with a rapid automatized naming test.

The BEVTA is composed of four subtests: Test of verbal similarities ('Test de semejanzas verbales'; 3-S), Test of naming of concepts grouped by categories ('Prueba de nominación de conceptos agrupados por categoría'; CAT-V), Test for immediate verbal assimilation ('Test de Asimilación Verbal Inmediata'; TAVI) and Verbal Series ('Series Verbales'; S-V). The 3-S, as well as the CAT-V subtests assess for categorizing skills. The 3-S tests for verbal abstraction and vocabulary (e.g., the examiner asks: 'En qué se parecen las tres cosas que te voy a decir, qué tienen en común o para qué sirven las tres. Anillo, collar, pulsera.' *I am going to tell you about three things. Tell me how they are similar, what do they have in common, or what is the use of all those three things. Ring, necklace, bracelet.*). The 3-S subtest contains 12 different lists of items, including different classes of objects, feelings, adjectives and verbs. The CAT-V subtest assesses verbal fluency as reflected in the ability to find other objects or concepts that fall in the same category as the ones given by the evaluator (e.g., the examiner says: 'Te voy a nombrar una palabra, trata de decirme el nombre de todas las cosas o cualidades semejantes

a las que te voy a nombrar. Cuaderno.' *I am going to name a word, try to tell me the name of all the things or adjectives similar to the one I named. Notebook. (the child is supposed to list school supplies).* The CAT-V subtest consists of 10 items.

We chose the TAVI and S-V, for being the most directly related to receptive language to check for the expected difference between DLDe and DLDer children, namely, DLDer children showing poorer receptive skills than DLDe children. Both tests also strongly address a verbal memory component. The TAVI subtest measures the skills to retain simple information, given orally (e.g., the examiner says: 'Para aprender a cantar bien hay que saber las notas musicales' *To learn how to sing well, you must know the musical notes.* Then the examiner asks: '¿Qué cosa deben saber los que cantan bien?' *What should good singers know?* The TAVI subtest has a total number of 10 items). The S-V subtest measures the ability to retain more complex information, than the one tested by the TAVI (e.g. the examiner says: ' En la T.V. dieron un programa de dibujos animados, seguido de un partido de fútbol, luego dieron una película de aventuras y finalmente las noticias' *On the television, they showed a cartoon show, followed by a football match, then they showed an adventure movie and finally the news.* Then the examiner says: '¿Cuáles programas dieron en la T.V?' *Which programmes were shown on the television?* The S-V subtest has a total number of 10 items. Validity tests, reported in the test´s manual, performed in 78 SRD children between 7 and 9 years of age, from low-SES, report a medium but significant correlation between scores obtained in the S-V and TAVI subtests with verbal IQ obtained with WISC-R, (S-V: r=0.30, p=0.05; TAVI: r=0.34, p=0.001; Bravo & Pinto, 1995). Additionally, a study by Bravo et al. (1988) reports a factor analysis over a sample of 63 TD and 93 SRD children (7;6 to 10;0 (y;m), both groups with typical intelligence) including the BEVTA and six subtests of the WISC-R: similarities, vocabulary, arithmetic, digit span, block design, picture coding. The results showed that a factor including S-V, 3-S and CAT-V, explained 39% of the common variance (h^2) in TD children. As for the SRD children, two factors explained the variance: one including the 3-S and the similarities test in the WISC-R, and another one including the TAVI and the S-V (Bravo & Pinto, 1987). Moreover, S-V and TAVI discriminate between 7 and 8-year-olds, and between SRD and TD children from low-SES (p=0.05 and p<0.05, respectively; t-values not reported). Reliability of items in the BEVTA was analysed with the Kuder-Richardson (K-R), and Spearman-Brown (S-B)

approaches: S-V, K-R=0.7 (n=50) and S-B=0.7 (n=40); TAVI, K-R=0.8 (n=112) and S-B=0.8 (n=40) (Test´s manual, Bravo L. & Pinto A., 1995). Similar results to those presented in the manual, are shown in Bravo (1995). In that study, 156 children (93 SRD and 63 RD, 7 to 9 years of age) took part and TD children outperformed SRD children in all subtests of the BEVTA battery.

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Abstract

Children with developmental language disorder (DLD) have an increased risk of developing reading difficulties. However, the DLD group is a heterogeneous group and individual children with DLD may be present with different challenges depending on particular weaknesses. This dissertation explores the effect of comprehension difficulties on reading development in children with DLD. By using different approaches, the dissertation studies the language and reading difficulties from a behavioural perspective by testing reading and general language skills, as well as from a neurophysiological point of view, by using event-related potential recordings. Moreover, the dissertation explores the possibility to use serious video-gaming as an intervention, as well as an early diagnostic tool. The results suggest that rapid automatized naming is a suitable predictor of reading skills in second grade. Additionally, the data suggest that brain responses in kindergarten and first grade are indicators of reading skills in second grade. Finally, the results suggest that GraphoGame, a serious-videogame designed to train phonological awareness and letter-sound association, may be beneficial for training early reading skills. Also, in-game data and game progress correlate with reading fluency in second grade, which suggests that GraphoGame can be used to not only support but also diagnose, at an early stage, children who become struggling readers later on. The results add to the field of reading and special educational needs, as well as suggest possible approaches to investigate reading training and diagnosis in children, from a distance.

Korte samenvatting

Kinderen met een taalontwikkelingsstoornis (TOS) hebben een verhoogd risico op het ontwikkelen van leesproblemen. De TOS-groep is echter een heterogene groep en de individuele kinderen met TOS kunnen afhankelijk van bepaalde zwakke punten met verschillende uitdagingen worden geconfronteerd. Dit proefschrift onderzoekt het effect van begripsproblemen op de leesontwikkeling bij kinderen met TOS. Door gebruik te maken van verschillende benaderingen bestudeert het proefschrift de taal- en leesproblemen vanuit een gedragsperspectief door het testen van lees- en algemene taalvaardigheden, alsmede vanuit een neurofysiologisch oogpunt, door gebruik te maken van event-related-potential registraties. Bovendien verkent het proefschrift de mogelijkheid om 'serious videogaming' als interventie te gebruiken, en eveneens als een vroeg diagnostisch hulpmiddel. De resultaten suggereren dat snel geautomatiseerd benoemen een geschikte voorspeller is van leesvaardigheid in de tweede klas [vgl. groep vier]. Daarnaast suggereren de gegevens dat de hersenrespons op de kleuterschool en in de eerste klas een indicator is voor leesvaardigheid in de tweede klas. Tot slot suggereren de resultaten dat GraphoGame, een serious videogame dat ontworpen is om het fonologisch bewustzijn en de letter-klankassociatie te trainen, gunstig kan zijn voor het trainen van vroege leesvaardigheden. Ook de gegevens in het spel en de voortgang van het spel hangen samen met de leesvaardigheid in de tweede klas, wat suggereert dat GraphoGame niet alleen kan worden gebruikt om kinderen die later moeite hebben met lezen te ondersteunen, maar ook om in een vroeg stadium een diagnose te stellen. De resultaten dragen bij aan de leesvaardigheid en de speciale onderwijsbehoeften, en suggereren mogelijke benaderingen om de leesvaardigheidstraining en -diagnose bij kinderen via een internettoepassing te onderzoeken.

Academic Summary

Reading skills are fundamental for academic development and success. Therefore, difficulties in learning to read strongly impact children´s school life, with a negative effect on their self-esteem. Children with developmental language disorder (DLD) have an increased risk of developing reading disability (RD). It has been shown that 20-50% of children with DLD develop RD.

DLD is characterized by a significant deficit in language comprehension and/or expression, that can not be explained by nonverbal, intellectual, emotional, motor, or sensory abilities. The deficits shown by a child determine whether he or she is diagnosed either as DLD with only expressive difficulties (DLDe), or with both expressive and receptive difficulties (DLDer). Because DLD is related to spoken language, it can be diagnosed as early as 3 years of age. In Chile, it affects around 4% of the general population and the prevalence has been shown to be strongly related to the socio-economic (SES) background. The prevalence of DLD in low-SES children can reach around 30% of children.

In this dissertation we explore the overlap between DLD and RD, as well as its relationship to different DLD-subtypes (DLDe or DLDer). By using event-related potential (ERP) recordings, we study the feasibility to find early neurophysiological indicators for RD in DLD children. Additionally, we study behavioural markers, especially related to comprehension difficulties, that may be used as traits predicting later reading difficulties. Moreover, we study the role that differences and commonalities between DLD and RD may be playing in the diagnosis of the DLD-subtypes. Finally, we study the diagnostic potential of GraphoGame (GG). GG is a computerized videogame designed to train reading-related skills, that may be used as diagnostic tool for reading difficulties while at the same time training reading-related skills.

Chapter 1 presents a general introduction to the topics of this thesis, giving a general overview of the current literature regarding reading and language difficulties. Additionally, it presents the aims of the studies presented, namely, finding specific neurocognitive and neurophysiological markers that may account for the heterogeneity found in DLD children, and the relationship between such heterogeneity and the development of RD.

Chapter 2 presents a study regarding the behavioural differences between DLDe and DLDer children, and their risk of developing RD. The study included different language and reading-related skills, as assessed in kindergarten or first grade and in second grade. The results show that DLDe children outperform their DLDer classmates in language-related skills in kindergarten and first grade. Moreover, it shows that rapid automatized naming is the language skill that best predicts reading fluency.

Chapter 3 reports the study of differences in phonological processing between typically developing (TD) and DLD participants. The study included ERP recordings, as well as behavioural assessments of phonological awareness and comprehension skills in kindergarten or first grade, and a reading fluency task in second grade. Results suggest that there are no difference in a particular component of the ERP, namely the mismatch response (MMR), between TD and DLD participants. However, the study reports a relationship between MMR and phonological awareness (PA), in that children with poorer PA showed larger late discriminative negativity (LDN), as compared to TD children. Similarly, children who became poor readers showed a larger LDN, as compared to those who became good readers. Finally, the study reports no relationship between MMR and comprehension skills.

Chapter 4 exposes the research on ERP differences in response to written stimuli between TD and DLD participants. Data analyzed included ERP recordings and comprehension skills assessed in kindergarten or first grade, as well as the results of a reading fluency task taken in second grade. Results suggest that the response to letter strings, as expressed by the print tuning (PT) component, is similar in both TD and DLD participants. Moreover, results showed no relationship between PT and comprehension skills. Interestingly, the results suggest a relatively larger PT in children who became good readers, as compared to those who became poor readers.

Chapter 5 presents a study on the effect of GraphoGame (GG) on reading-related skills, as well as the differences in in-game progress in DLDe, DLDer and TD children. The study explored the effect over a 6-weeks intervention programme taken in kindergarten or first grade. Additionally, chapter 5 reports on the in-

game progress of children who became good and poor readers, as assessed in second grade. Results suggest that children improved in all reading-related skills assessed, regardless of the test. Additionally, DLDer children made less progress in the game, as compared to TD and DLDe children. Similarly, children who became poor readers made less progress than those participants who became good readers. Finally, there is a strong correlation between performance at the first level (out of 14) in GG , and reading fluency as assessed in second grade.

Chapter 6 discusses the results presented in the previous chapters in light of the current literature, presenting limitations and future development of the research presented in the dissertation.

The Appendix characterizes the clinical population studied in the current dissertation, by presenting the process to diagnose DLDe and DLDer in Chile. Additionally, the appendix presents the complementary tests conducted to further study the differences and commonalities between DLDe and DLDer.

Academische samenvatting

Leesvaardigheid is fundamenteel voor academische ontwikkeling en succes. Daarom hebben moeilijkheden met het leren lezen een sterke invloed op het schoolleven van kinderen, met een negatief effect op hun gevoel van eigenwaarde. Kinderen met een taalontwikkelingsstoornis (TOS; Engelstalig: developmental language disorder (DLD)) hebben een verhoogd risico op het ontwikkelen van leesproblemen. Het is aangetoond dat 20-50% van de kinderen met TOS leesproblemen ontwikkelen.

TOS wordt gekenmerkt door een significant tekort aan taalbegrip en/of uitdrukkingsvaardigheid, dat niet verklaard kan worden uit non-verbale, intellectuele, emotionele, motorische of zintuiglijke tekorten. De tekorten die een kind vertoont, bepalen of het gediagnosticeerd wordt als TOS met alleen expressieproblemen (TOSe), of met zowel expressieve als receptieve problemen (TOSer). Omdat TOS gerelateerd is aan gesproken taal, kan de diagnose vanaf 3 jaar worden gesteld. In Chili treft het ongeveer 4% van de algemene bevolking en de prevalentie is sterk gerelateerd aan de sociaal-economische (SES) achtergrond. De prevalentie van TOS bij kinderen met een lage SES kan oplopen tot ongeveer 30% van de kinderen.

In dit proefschrift onderzoeken we de overlap tussen TOS en leesproblemen, evenals de relatie met de verschillende TOS-subtypes (TOSe of TOSer). Door gebruik te maken van event-related potential (ERP) metingen onderzoeken we of we vroege neurofysiologische indicatoren kunnen vinden voor leesproblemen bij TOS-kinderen. Daarnaast bestuderen we gedragsindicatoren, vooral met betrekking tot begripsproblemen, die gebruikt kunnen worden om latere leesproblemen te voorspellen. Bovendien bestuderen we de rol die de verschillen en overeenkomsten tussen TOS en leesproblemen kunnen spelen bij de diagnose van de TOS-subtypes. Tot slot bestuderen we het diagnostisch potentieel van GraphoGame (GG). GG is een computergestuurde videogame die ontworpen is om leesgerelateerde vaardigheden te trainen, maar die ook gebruikt kan worden als diagnostisch hulpmiddel voor leesproblemen, terwijl tegelijkertijd leesgerelateerde vaardigheden getraind worden.

Hoofdstuk 1 geeft een algemene inleiding op de onderwerpen van dit proefschrift en geeft een algemeen overzicht van de huidige literatuur op het gebied van lees- en taalproblemen. Daarnaast worden de doelstellingen van de studies in dit proefschrift gepresenteerd, namelijk het vinden van specifieke neurocognitieve en neurofysiologische indicatoren die de bij TOS kinderen gevonden heterogeniteit kunnen verklaren, en de relatie tussen deze heterogeniteit en de ontwikkeling van leesproblemen.

Hoofdstuk 2 presenteert een onderzoek naar de gedragsmatige verschillen tussen TOSe en TOSer kinderen, en hun risico op het ontwikkelen van leesproblemen. Het onderzoek omvatte verschillende taal- en leesvaardigheden, zoals die geëvalueerd waren op de kleuterschool of in de eerste klas [vgl. groep 3] en in de tweede klas [vgl. groep 4]. De resultaten laten zien dat TOSe kinderen beter presteren dan hun TOSer klasgenoten in taalgerelateerde vaardigheden op de kleuterschool en in de eerste klas. Bovendien laat het zien dat geautomatiseerd snel serieel benoemen (SSB; Engelstalig: RAN) de taalvaardigheid is die de leesvaardigheid het beste voorspelt.

Hoofdstuk 3 rapporteert de studie van verschillen in de fonologische verwerking tussen zich normaal ontwikkelende (NO) en TOS-deelnemers. De studie omvatte ERP-registraties, evenals gedragsmatige evaluatie van het fonologische bewustzijn (FB), de begripsvaardigheden op de kleuterschool of in de eerste klas, en een leesvaardigheidsopdracht in de tweede klas. De resultaten suggereren dat er in een bepaalde component van de ERP, namelijk de mismatch respons (MMR), geen verschil is tussen NO en TOS deelnemers. De studie laat echter ook een relatie tussen de MMR en het fonologische bewustzijn (FB) zien, in die zin dat kinderen met een zwakker FB een grotere late discriminerende negativiteit (LDN) vertoonden, in vergelijking met NO kinderen. Evenzo vertoonden kinderen die slechte lezers werden, een grotere LDN in vergelijking met degenen die goede lezers werden. Tot slot vond het onderzoek geen verband tussen MMR en begripsvaardigheden.

Hoofdstuk 4 presenteert het onderzoek naar ERP-verschillen in de respons op visueel aangeboden letterreeksen (woorden, pseudowoorden) tussen NO en TOS-deelnemers. De geanalyseerde gegevens omvatten ERP-registraties en

begripsvaardigheden die geëvalueerd waren op de kleuterschool of in de eerste klas, en de resultaten van een leesvloeiendheidstest die is afgenomen in de tweede klas. De resultaten suggereren dat de respons op de letterreeksen, zoals uitgedrukt in de 'print tuning' (PT) component, vergelijkbaar is voor de NO en TOS deelnemers. Bovendien bleek uit de resultaten dat er geen verband bestaat tussen PT en begripsvaardigheden. Interessant is dat de resultaten suggereren dat bij kinderen die goede lezers werden, de PT relatief groter is dan bij kinderen die slechte lezers werden.

Hoofdstuk 5 presenteert een onderzoek naar het effect van GraphoGame (GG) op leesgerelateerde vaardigheden, alsmede de verschillen in vooruitgang in het spel bij TOSe, TOSer- en NO-kinderen. De studie onderzocht het effect gedurende een interventieprogramma van zes weken op de kleuterschool of in de eerste klas. Daarnaast wordt in hoofdstuk 5 verslag gedaan van de vooruitgang in het spel van kinderen die goede en slechte lezers zijn geworden, zoals beoordeeld in de tweede klas. De resultaten suggereren dat kinderen bij alle beoordeelde leesgerelateerde vaardigheden vooruitgang hebben geboekt, ongeacht de test. Daarnaast hebben TOSer kinderen minder vooruitgang geboekt in het spel, in vergelijking met NO en TOSe kinderen. Ook boekten kinderen die slechte lezers werden, minder vooruitgang dan de deelnemers die goede lezers werden. Tot slot is er een sterke correlatie tussen de prestaties op het eerste niveau (van 14) in GG, en het vloeiend lezen zoals beoordeeld in de tweede klas.

Hoofdstuk 6 bespreekt de resultaten die in de voorgaande hoofdstukken zijn gepresenteerd in het licht van de huidige literatuur, waarbij de beperkingen en de toekomstige ontwikkeling van het in het proefschrift gepresenteerde onderzoek worden besproken.

De bijlage karakteriseert de klinische populatie die in het huidige proefschrift is bestudeerd, door een beschrijving te geven van het proces om TOSe en TOSer in Chili te diagnosticeren. Daarnaast presenteert de bijlage de aanvullende testen die zijn uitgevoerd om de verschillen en overeenkomsten tussen TOSe en TOSer verder te kunnen bestuderen.

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